9-9042

REQ. NO. 9-9042

CONTRACT REPORT NO. OSQ79-00122

Determination of Wear on an ICE-CI Injection Pump Handling 15% Water/Diesel Fuel Emulsion

FINAL REPORT

ORF Contract No. 36005

For: Energy, Mines and Resources Canada
CANMET
Mining Research Laboratories
980 Booth Street
Ottawa, Ontario
K1A 0G1

Attention: Mr. E.D. Dainty
Scientific Officer

M.B. SHAW

COMBUSTION TECHNOLOGY CENTRE
DEPARTMENT OF ENGINEERING AND METALLURGY

March 31st, 1982

ONTARIO RESEARCH FOUNDATION

SHERIDAN PARK RESEARCH COMMUNITY

MISSISSAUGA, ONTARIO, CANADA L5K 1B3 • (416) 822-4111 • TELEX 06-982311

32 pp

WE, THE ONTARIO RESEARCH FOUNDATION, STIPULATE THAT THIS DOCUMENT IS SUBJECT TO THE FOLLOWING TERMS AND CONDITIONS:

1. ANY PROPOSAL CONTAINED HEREIN WAS PREPARED FOR THE CONSIDERATION OF THE ADDRESSEE ONLY. ITS CONTENTS MAY NOT BE USED BY NOR DISCLOSED TO ANY OTHER PARTY WITHOUT OUR PRIOR WRITTEN CONSENT.
2. ANY TESTING, INSPECTION OR INVESTIGATION PERFORMED BY US WILL BE CONDUCTED IN ACCORDANCE WITH NORMAL PROFESSIONAL STANDARDS. NEITHER WE NOR OUR EMPLOYEES SHALL BE RESPONSIBLE FOR ANY LOSS OR DAMAGE RESULTING DIRECTLY OR INDIRECTLY FROM ANY DEFAULT, ERROR OR OMISSION.
3. ANY REPORT, PROPOSAL OR QUOTATION PREPARED BY US REFERS ONLY TO THE PARTICULAR MATERIAL, INSTRUMENT OR OTHER SUBJECT REFERRED TO IN IT. NO REPRESENTATION IS MADE THAT SIMILAR ARTICLES WILL BE OF LIKE QUALITY.
4. NO REPORT ISSUED BY US SHALL BE PUBLISHED IN WHOLE OR IN PART WITHOUT OUR PRIOR WRITTEN CONSENT.
5. OUR NAME SHALL NOT BE USED IN ANY WAY IN CONNECTION WITH THE SALE, OFFER OR ADVERTISEMENT OF ANY ARTICLE, PROCESS OR SERVICE.
6. WE RESERVE THE RIGHT NOT TO COMMENCE AND/OR CONTINUE ANY WORK UNTIL PAYMENT ARRANGEMENTS SATISFACTORY TO US ARE ESTABLISHED.

Determination of Wear On An ICE-CI Injection Pump Handling 15% Water/Diesel Fuel Emulsion

FINAL REPORT

For

Energy, Mines and Resources Canada

ORF Contract No. 36005

SUMMARY

A Bosch injection pump, Model #PE6AM75D and nozzles representative of a diesel fuel injection system for CI engines was operated on a closed loop test bench system for 3500 hours using a fuel emulsion of 15% water and 85% No. 2 diesel fuel. The test bench system was designed to simulate operation of a given mine vehicle operating through a defined load, haul and dump cycle. Qualitative analysis was performed on the injection pump, nozzles and support system components during and upon completion of the test program. Problems relating to wear and erosion of the system components as a result of the fuel emulsion are identified.

TABLE OF CONTENTS

		Page Number
	SUMMARY	
1.	INTRODUCTION	1
2.	APPARATUS	1
3.	TEST RESULTS	3
4.	DISCUSSION OF RESULTS	16
5.	CONCLUSIONS	17
	ACKNOWLEDGEMENTS	18
	REFERENCES	19
	FIGURE 1: SECTIONAL VIEW OF BOSCH "TYPE AM" FUEL INJECTION PUMP	4
	FIGURE 2: SCHEMATIC OF TEST BENCH SYSTEM	5
	FIGURE 3: BOSCH INJECTION SYSTEM AND TEST BENCH SYSTEM	6
	FIGURE 4: HYDROSHEAR INLET PRESSURE	11
	FIGURE 5: SYSTEM PRESSURE	12
	FIGURE 6: BOSCH SUPPLY PUMP PRESSURE	13
	FIGURE 7: EMULSION TEMPERATURE	14
	FIGURE 8: PERCENT WATER IN EMULSION	15
	TABLE I: SYSTEM OPERATING PARAMETERS	10
	APPENDIX I: BOSCH INJECTION PUMP SIZE "A" SPECIFICATIONS	
	APPENDIX II: ANALYSIS AND CONCLUSIONS BY ROBERT BOSCH CORPORATION, GERMANY	

DSS Fuel Pump Project
Final Report
ORF Contract No. 36005

1. INTRODUCTION

With increasing concerns of energy economics surrounding the use of petroleum-based fuels, an international effort has evolved to develop alternate fuel resources. The transportation industry has become a major focus of these efforts with a wide range of alternatives presented[1].

In the case of compression ignition (CI) engines, partial substitution of diesel fuel with these alternatives, i.e. methyl and ethyl alcohol, water, etc., has been accomplished with some degree of success[2]. Of particular interest to mining operations is the reduction in carcinogenic particulates which are indicated by the utilization of these emulsion fuels[3,4].

Although certain benefits are realized in the application of emulsion fuels on CI engines, the tribological nature of these fluids with respect to wear on engine and fuel system components must be investigated.

The primary objective of this program is to qualitatively evaluate the wear and erosion that would occur on a selected CI injection pump and its supporting components when operated on a 15% water/85% diesel fuel emulsion. The fuel injection system selected and the methodology used in this program typically represents the application of a given mine vehicle operating through a load-haul-dump duty cycle.

2. APPARATUS

The fuel injection assembly utilized for this study consisted of a Bosch #PE6AM75D fuel pump and six Bosch #US-31902 nozzles. This system was designed for multi-fuel operation and is suitable for installation on a Deutz F62714 diesel engine, typical of power plants used in mine vehicles as outlined previously. A sectional view of this type of pump is shown in Figure 1, and Original Equipment Manufacturers (OEM) Specifications are listed in Appendix I.

A closed loop test bench system was designed and assembled to manage and monitor operational parameters as defined by the application. A schematic of the fluid circuit is shown in Figure 2 and is described as follows.

Water and diesel fuel flow is proportioned to nominally 15% and 85% respectively using a fluidic proportioning device developed specifically for this application. The Magikist pump then increases the pressure of the fuel mixture to approximately 1380 kPa (~200 lb/in^2) which is required for the ORF HydroShear to prepare the final emulsion. Pressure between the Magikist pump and the HydroShear is regulated by PRV_1. Details on the design and application of the HydroShear are given in reference 5.

The emulsion then enters the Bosch injection pump where a portion is metered to the barrels of the individual pumping elements. The volume of fuel emulsion metered is usually dependent on engine speed and load determined primarily by the rack position. Fuel pressure is increased by the pumping elements to 7500-12,400 kPa (1100-1800 lb/in^2) which is required by the injector nozzles to overcome combustion chamber pressure. In this particular closed loop system the fuel emulsion from the nozzles returns to the reservoir for recirculation. The remainder of the fuel emulsion in the injection pump not metered to the pumping elements is utilized for cooling and lubrication. The excess emulsion then returns to the reservoir through a pressure relief valve PRV_2 which maintains system pressure at 100-150 kPa (14.5-21.8 lb/in^2).

The Bosch supply pump, incorporated into a parallel loop on the fluid circuit, circulates proportioned water/diesel fuel mixture through a filter and back to the reservoir. Pressure regulator PRV_3 maintains pressure in this loop at 100-150 kPa (14.5-21.8 lb/in^2), the OEM specified system pressure. Normally this pump supplies fuel to the injection pump but in this application it is replaced by the Magikist pump which provides the higher pressure required for the HydroShear. Since it may be feasible to

utilize the OEM supply pump for mixing or emulsifying devices other than the ORF HydroShear, it was retained in the circuit to determine the amount of wear and erosion attributable to a water/diesel fuel mixture.

Figure 3 shows the test bench system just prior to completion and start-up.

3. TEST RESULTS

The operating cycle (duty cycle) was checked prior to initiation of the test program. The results were as follows:

Cycle No.	Pump Speed (RPM)		Duration (seconds)	
	Specified	Actual	Specified	Actual
1	1100	1080	10	10
2	800	780	30	29
3	1100	1080	85	85
4	800	780	5	5
5	1100	1080	80	80

Qualitative analysis and operating parameters were monitored on a daily basis throughout the test program. Table I presents data on system pressures and emulsion temperature and percentage at approximately 250 hour intervals. Figures 4, 5 and 6 are graphs plotted from data presented in Table I showing system pressures, P_1, P_2 and P_3 respectively. Figures 7 and 8 show emulsion temperature and percentage, also plotted at 250 hour intervals from data shown in Table I.

The following results were indicated through the on-going qualitative analysis.

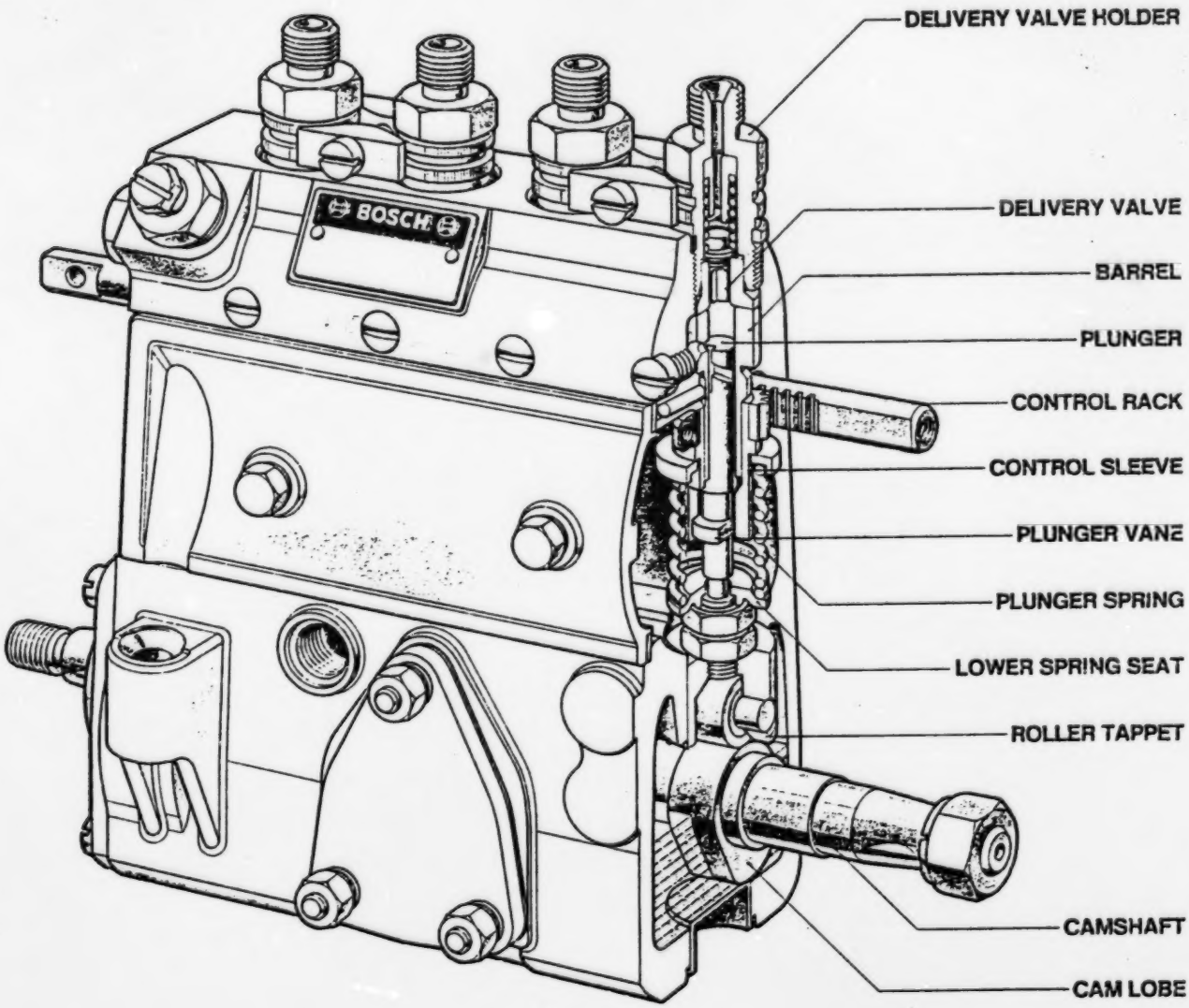


FIGURE 1

SECTIONAL VIEW OF A BOSCH "TYPE AM" FUEL INJECTION PUMP

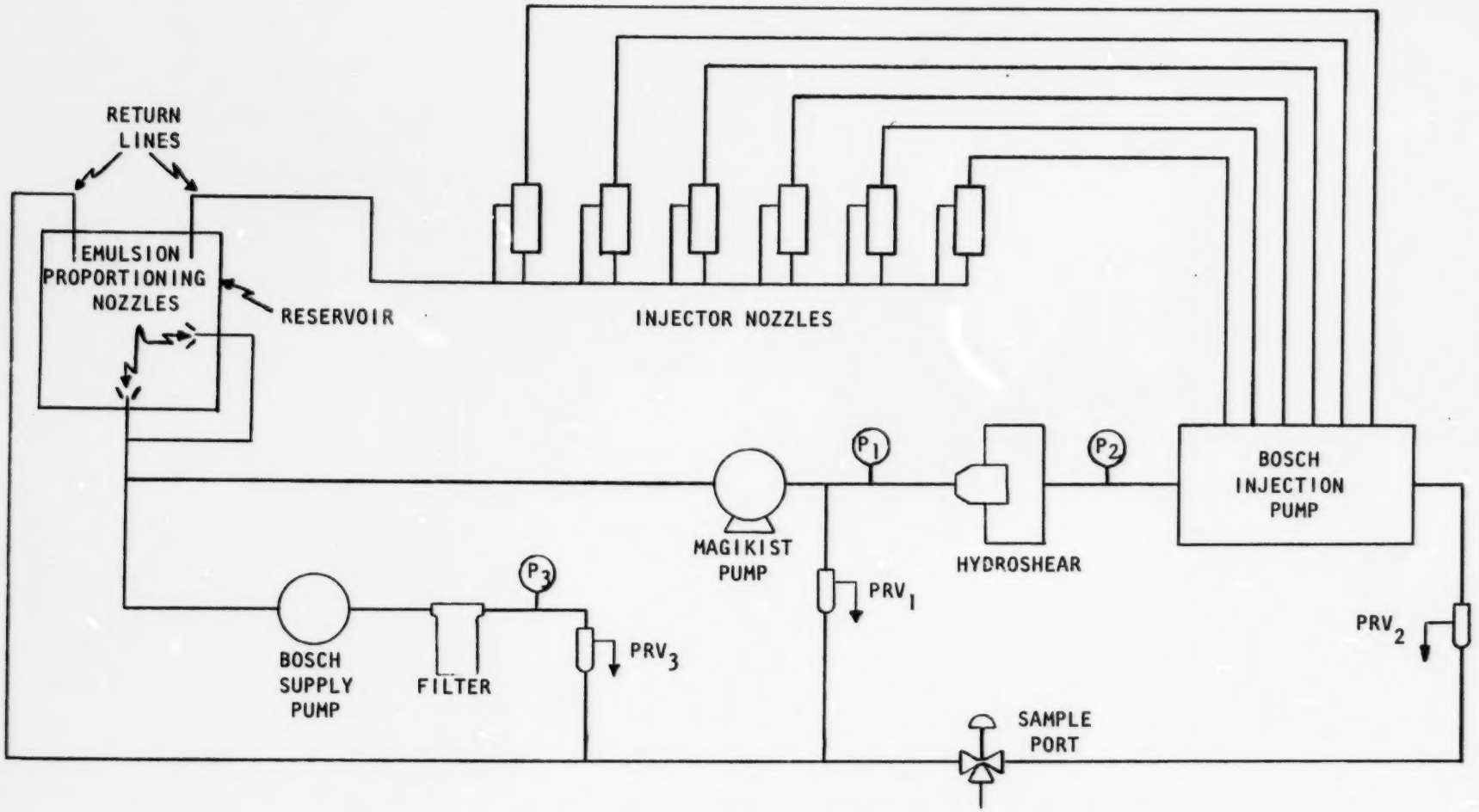


FIGURE 2: Schematic of Test Bench System

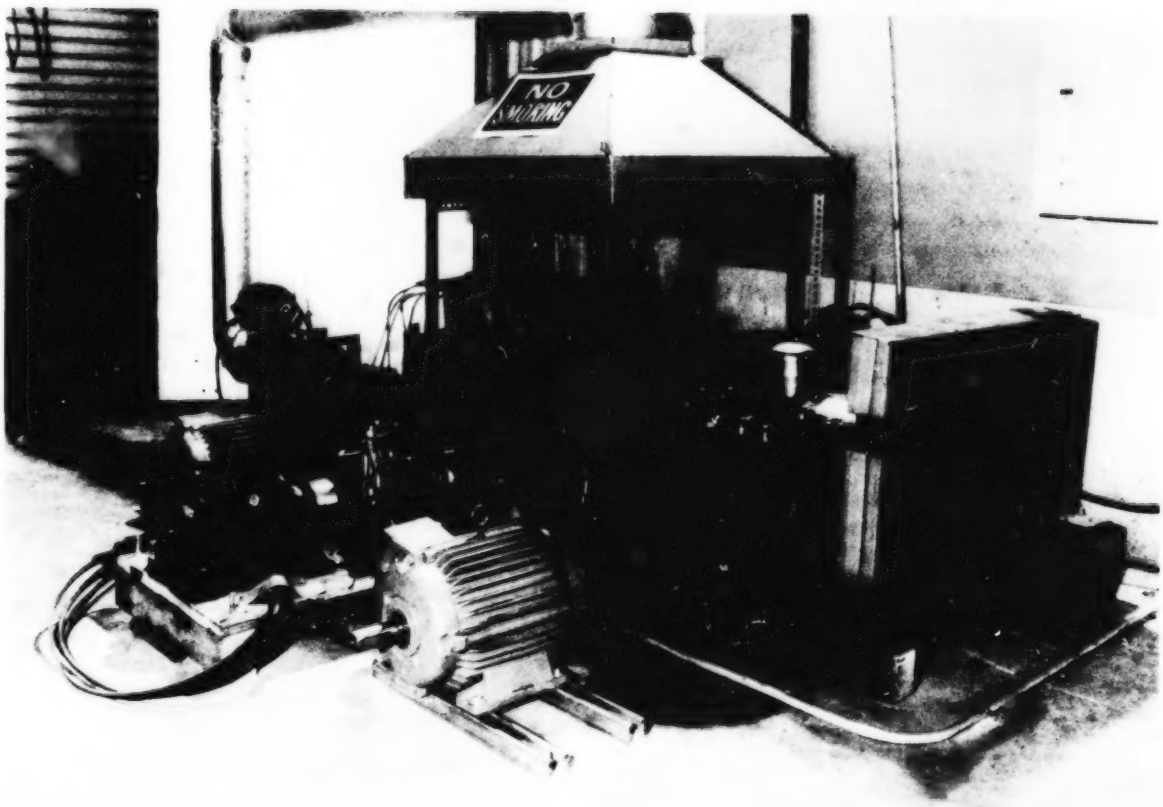


FIGURE 3

BOSCH INJECTION SYSTEM AND TEST BENCH SYSTEM

At approximately 650 hours the inlet pressure (P_1) to the HydroShear and system pressure (P_2) dropped below minimum specifications (Figures 4 and 5). Fluid leakage was also observed between the pistons and cylinders of the Magikist pump. Further analysis indicated that the pernap seals, located between the pistons and cylinders, were severely scored. Since the pump had been used on previous programs we were not able to ascertain the cause of scoring. New seals were installed and system pressures were re-adjusted to specifications.

Upon analysis of the lubricating oil in the sump of the Bosch pump, it was observed at approximately 1400 hours that the fluid level was above that which is recommended. Dilution of the lubricating oil with diesel fuel was evident and indicated that wear had occurred between the pump's plungers and barrels. Leakage of diesel fuel into the lubricating sump progressively increased as the test program continued.

At approximately 1500 hours an increase in HydroShear inlet pressure (P_1) and a decrease in system pressure (P_2) was observed (Figures 4 and 5). Further analysis indicated binding of the poppet valve in pressure regulator PRV_1. The valve was disassembled, inspected, cleaned and re-installed. Since damage was not apparent during inspection it is suspected that foreign matter in the emulsion had caused the binding.

At 3000 hours a noticeable deterioration in nozzle atomization quality was evident and metal particles were observed in the water and diesel fuel diluted lubricating oil. The test program was terminated at 3525 hours as a result of these problems and upon recommendation of a Bosch Senior Service Engineer.

Just prior to shut-down it was observed that the Bosch supply pump circuit pressure (P_3) had increased well above the specified upper limit. Analysis indicated that binding of the poppet valve in pressure regulator PRV_3 had occurred. Corrosion to the internal surface of the regulator was determined as the cause of failure.

Upon completion of the test program the components of the test bench system were analysed for damage, wear and/or erosion by ORF personnel. Following are the results of this analysis.

Surface corrosion was observed on the internal surfaces of the Magikist pump, ORF HydroShear, pressure regulators and the filter housing.

Scoring of the seals in the Magikist pump was again evident. Leakage of water and diesel fuel between the pistons and cylinders, as a result of damaged seals, was observed prior to test termination.

Generally all other components of the test bench system appeared to be in satisfactory condition.

The injection pump and nozzles were sent to Robert Bosch GmbH in Germany for detailed analysis by their Development Department. The results and conclusions from this analysis are detailed in Appendix II and outlined as follows.

Corrosion was observed on the following components:

- delivery valve springs
- delivery valve holders
  - at the high pressure line threads
  - on the inside diameter of valve holder where the delivery valve spring rubs against the holder
- delivery valve
  - on the unground areas of the body and partly on the pins
- pumping element
  - large areas on the outside diameter of the element barrel collar
  - partly in the suction and leak-oil holes and the milled regions of the helix

- filling piece
  - partly on surface

- supply pump
  - areas exposed to the fuel mixture on the housing and handprimer plunger
  - light rust on the supply pump spring

Failure to all delivery valve springs had occurred with breakage observed at the first or second coil of each spring. The failure was attributable to rust formation on the springs as indicated previously.

Failure had occurred to all components of camshaft ball bearing, located at the governor end of the injection pump. Failure to the bearing was considered by Bosch to be a result of severe loading during the test program.

Indentations on the high pressure sectors of the cam lobes was observed and considered as a result of dirt in the lubricating oil. Dirt was also found in the supply pump cavities.

In general, all components other than the delivery valve springs and the governor end bearing were considered to be in satisfactory condition.

TABLE I

SYSTEM OPERATING PARAMETERS
AT ~250 HOUR INTERVALS

Hours	Date	Number of Cycles	P_1 kPa (lb in/2)	P_2 kPa (lb in^2)	P_3 kPa (lb in^2)	T ^oC (^oF)	% Water in Emulsion
2	81-2-18	34	1276 (185)	138 (20)	83 (12)	23 (74)	10
199	81-2-27	3413	1310 (190)	145 (21)	83 (12)	35 (95)	16
387	81-3-7	6638	1344 (195)	124 (18)	124 (18)	19 (67)	15
587	81-3-17	10056	1241 (180)	83 (12)	124 (18)	24 (76)	16
759	81-3-27	13009	1344 (195)	124 (18)	117 (17)	22 (72)	15
933	81-4-23	15997	1344 (195)	110 (16)	124 (18)	17 (62)	13
1189	81-5-4	20386	1379 (200)	117 (17)	97 (14)	16 (60)	13
1392	81-5-14	23869	1379 (200)	138 (20)	103 (15)	16 (60)	16
1677	81-5-29	28741	1379 (200)	97 (14)	90 (13)	29 (84)	18
1883	81-6-12	32276	1551 (225)	93 (13.5)	152 (22)	28 (82)	15
2046	81-6-19	35071	1413 (205)	90 (13)	131 (19)	27 (80)	19
2254	81-6-30	38636	1448 (210)	90 (13)	83 (12)	30 (86)	17
2480	81-7-11	42512	1482 (215)	110 (16)	124 (18)	16 (60)	15
2673	81-7-23	45827	1379 (200)	131 (19)	76 (11)	28 (82)	14
2853	81-7-31	48901	1379 (200)	138 (20)	138 (20)	26 (78)	13
2983	81-8-6	51141	1448 (210)	152 (22)	124 (18)	28 (82)	16
3143	81-8-14	53381	1448 (210)	124 (18)	131 (19)	27 (80)	15
3304	81-8-21	56640	1448 (210)	117 (17)	117 (17)	28 (82)	16
3469	81-8-28	59465	1448 (210)	124 (18)	124 (18)	27 (80)	15
3525	81-9-1	60424	1413 (205)	124 (18)	Over Range	27 (80)	15

P_1 - Magikist Pump Pressure Before HydroShear

P_2 - System Pressure After HydroShear

P_3 - Bosch Supply Pump Pressure

T - Fluid Temperature in Reservoir

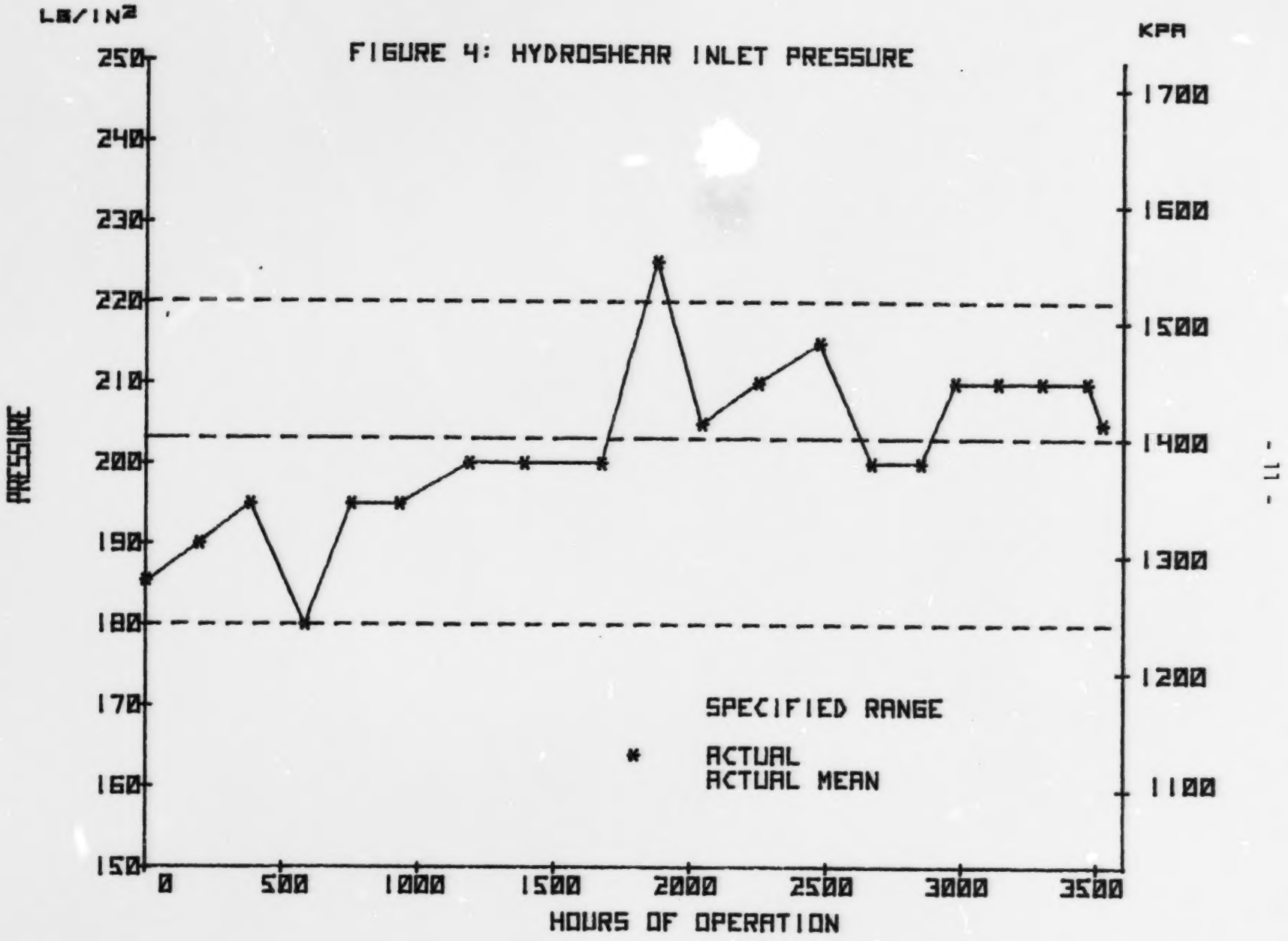


FIGURE 4: HYDROSHEAR INLET PRESSURE
LB/IN²
KPA
PRESSURE
250
240
230
220
210
200
190
180
170
160
150
1700
1600
1500
1400
1300
1200
1100
0
500
1000
1500
2000
2500
3000
3500
HOURS OF OPERATION
SPECIFIED RANGE
* ACTUAL
ACTUAL MEAN

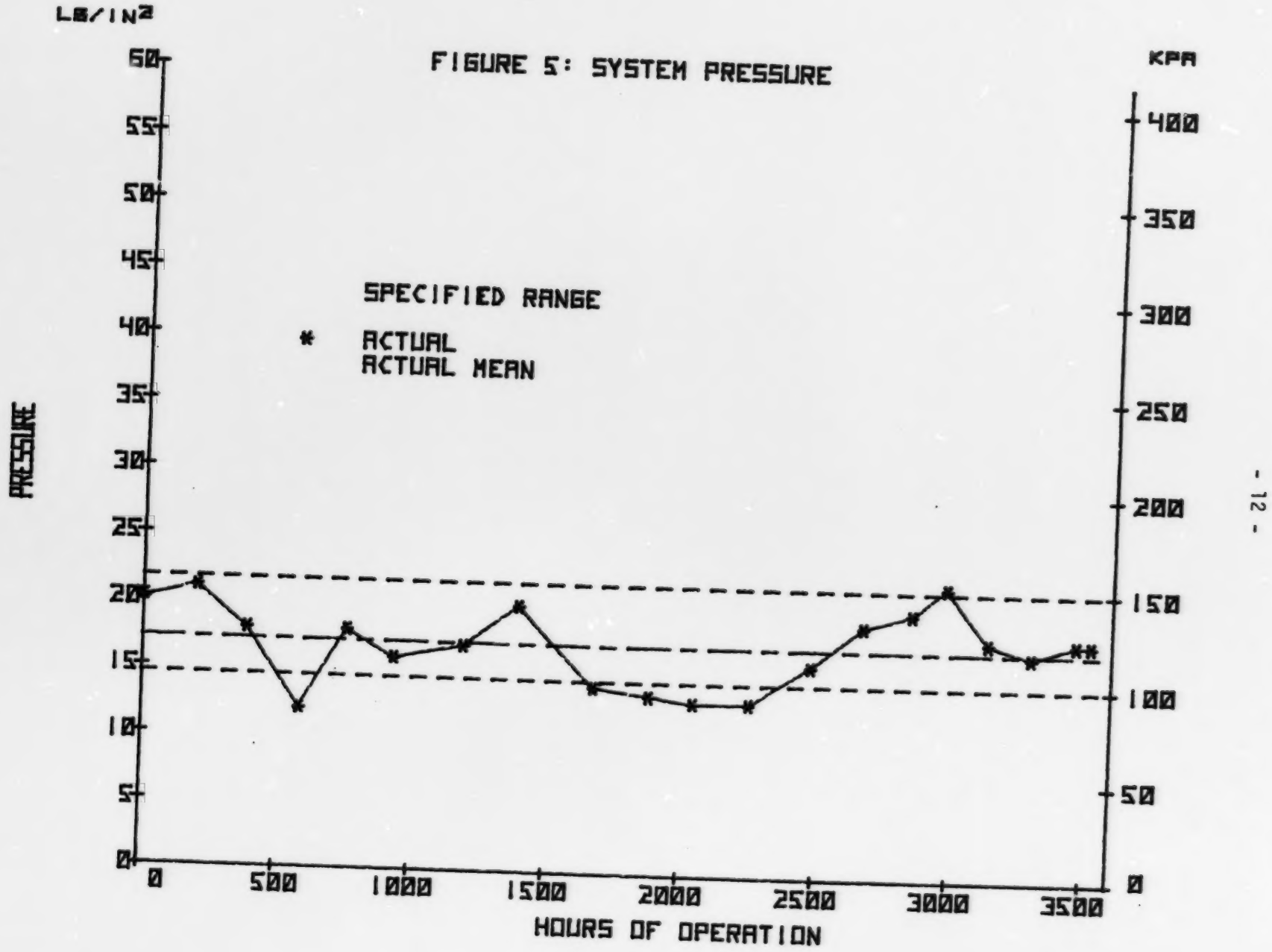
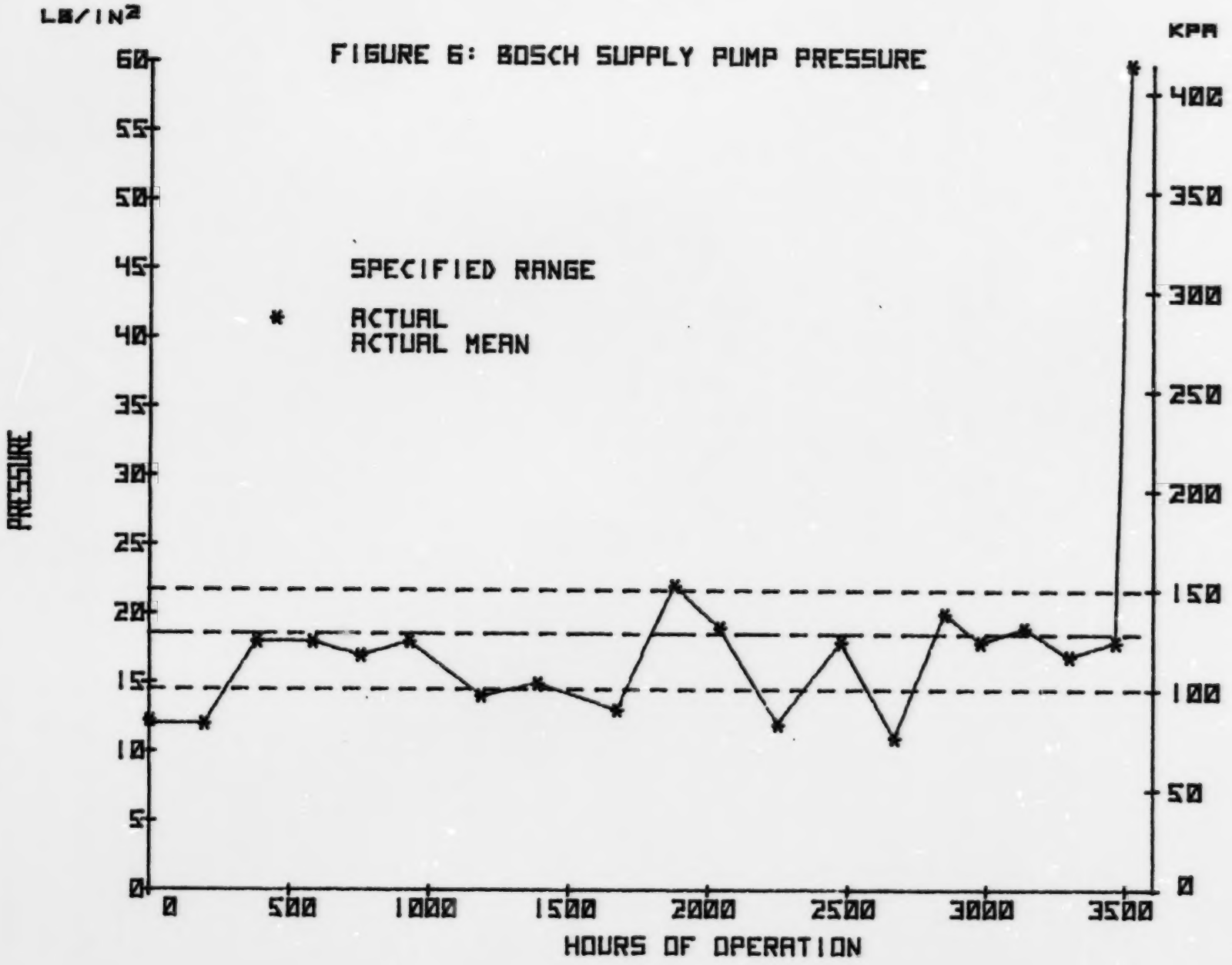


FIGURE 5: SYSTEM PRESSURE
LB/IN2
KPA
PRESSURE
HOURS OF OPERATION
SPECIFIED RANGE
* ACTUAL
ACTUAL MEAN
60
55
50
45
40
35
30
25
20
15
10
5
0
400
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500


LB/IN²
KPA
FIGURE 6: BOSCH SUPPLY PUMP PRESSURE
SPECIFIED RANGE
* ACTUAL
ACTUAL MEAN
PRESSURE
60
55
50
45
40
35
30
25
20
15
10
5
0
400
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
HOURS OF OPERATION

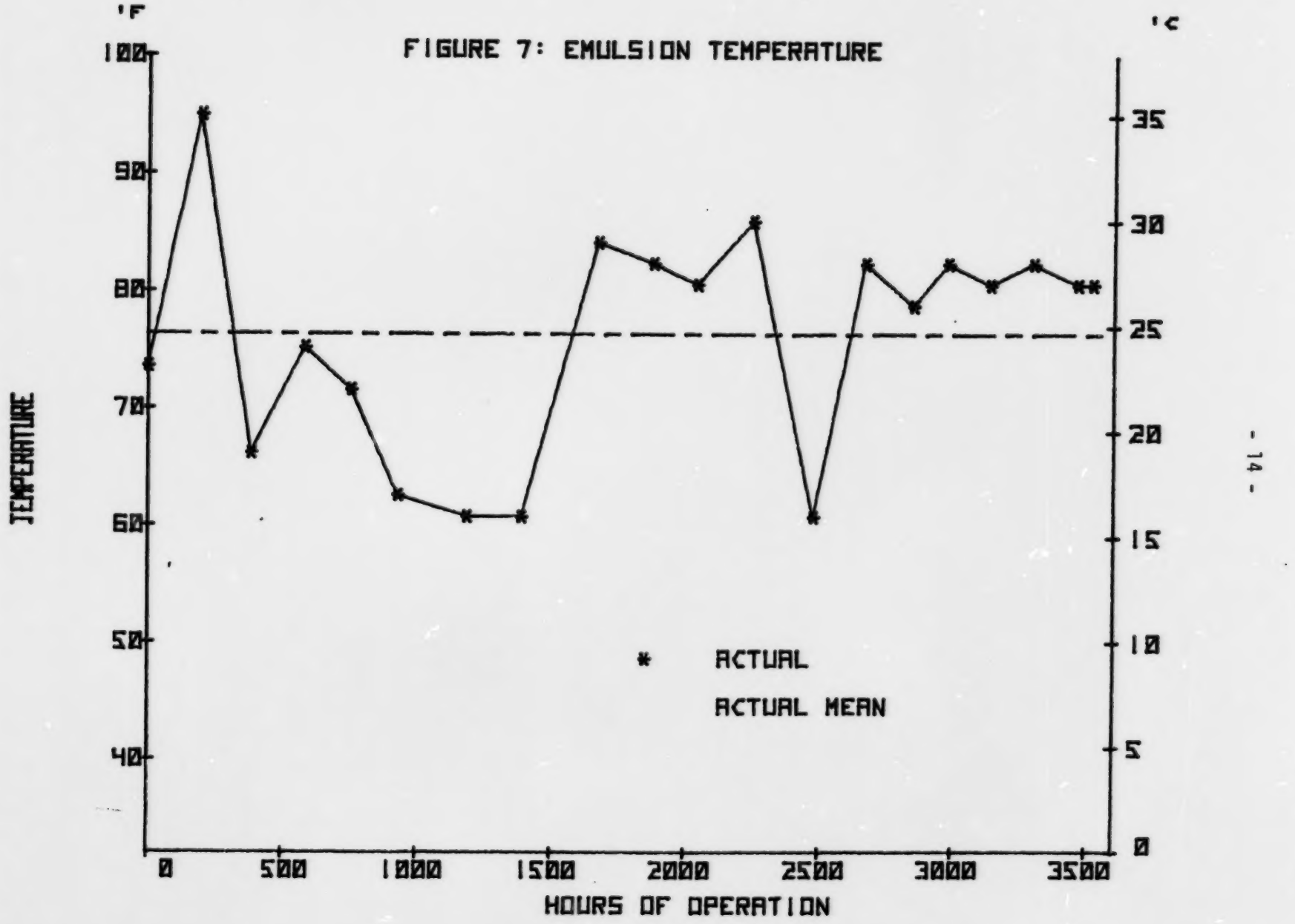
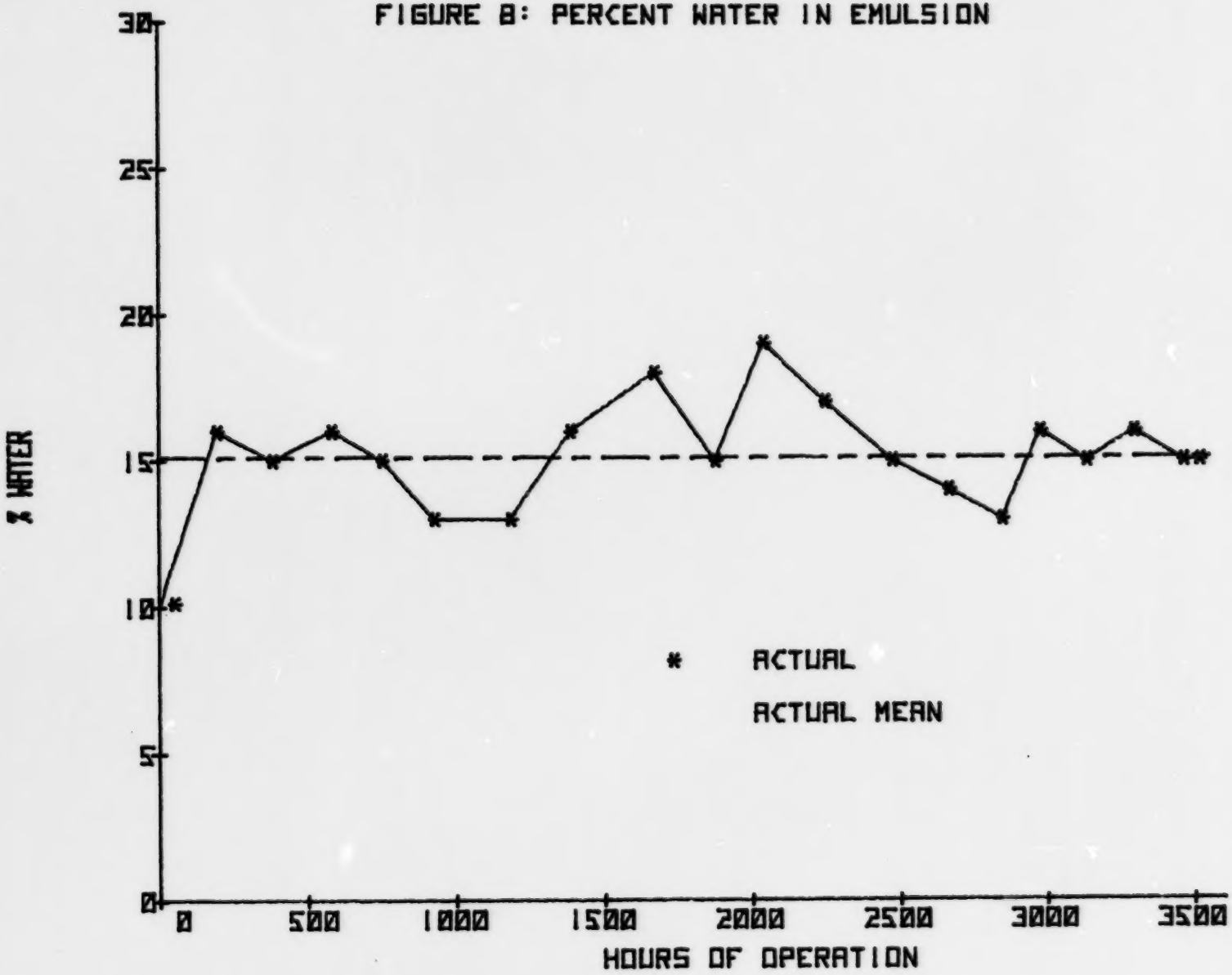


FIGURE 7: EMULSION TEMPERATURE
'F
'C
100
90
80
70
60
50
40
35
30
25
20
15
10
5
0
TEMPERATURE
* ACTUAL
ACTUAL MEAN
0
500
1000
1500
2000
2500
3000
3500
HOURS OF OPERATION

FIGURE 8: PERCENT WATER IN EMULSION



4. DISCUSSION OF RESULTS

The results as presented through the analysis performed by ORF and Robert Bosch Corporation appeared, in most part, conclusive as to the extent of wear, damage and erosion.which may occur to a CI fuel injection system that is operated on a water/diesel fuel emulsion. There are however certain areas of concern which require further explanation and/or investigation.

It was indicated by Robert Bosch Corporation and supported by ORF that even though the findings of this test program appear favourable, the results cannot be generalized for applications on a larger scale involving water/diesel fuel emulsions. Such factors as emulsion temperature, extent of engine idle time, composition of water and generally the application of the equipment may significantly affect the life expectancy of system components.

With reference to the failure of the governor end bearing and the cause of failure indicated by Robert Bosch Corporation, we are in full agreement that abnormal loading of the injection pump may have been experienced during the test program. The rate of acceleration between speed changes or cycle changes is considered to be significantly greater on the test bench system than that of practical application on a CI engine. The area of questionable concern though, is the cumulative effects of metal particle and water/diesel fuel contamination of the lubricating oil on the premature failure of this bearing. We therefore consider the cause of failure to this component is not completely ascertainable.

Analysis by Bosch also failed to mention the presence of metal particles and water/diesel fuel in the sump of the injection pump. These substances may have been defined as "dirt" since an analysis was not performed to

determine the actual constituents. Metal oxides are also a likely component of this substance. It is suspected that these substances were formed in the system but further investigation is required to determine the actual constituents and their source. Samples of the lubricating oil were taken at intervals through the test program and may be analyzed at a later date if necessitated.

As a point of interest, this particular injection pump was designed for multi-fuel application and incorporates a feature which may reduce wear to the pump's plungers and nozzles when used with low lubricity fuels, ie.water, methanol, ethynol, etc. Presented in figure 9 is a sectional view of the pumping element used for multi-fuel application. An additional oil passage (oil block) is shown and is used to seal and lubricate the mating surfaces of the plunger and barrel. The oil to this passage is supplied under pressure from the engine's lubricating system. This feature was not used in the test program as it was defined that wear and erosion was to be determined for a typical CI injection pump application. It should be understood that additional lubrication in this area of multi-fuel injection pumps would significantly reduce wear to the plungers and bushings and also reduce contamination of the pump's lubricating oil, a problem which we suspect constituted to the component failures identified.

CONCLUSIONS

The following conclusions and recommendations are presented through the results of analysis performed by ORF and Robert Bosch GmbH, Germany.

The fuel injection pump and support system components operated within OEM specifications through the normal life expectancy period of approximately 3000 hours.

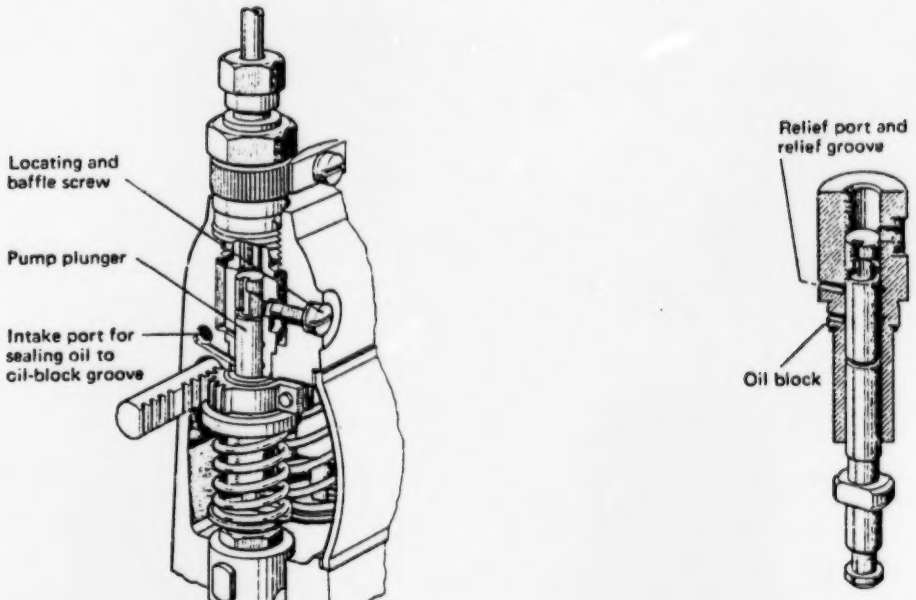

Locating and baffle screw
Pump plunger
Intake port for sealing oil to oil-block groove
Relief port and relief groove
Oil block

FIGURE 9

SECTIONAL VIEW OF MULTI-FUEL PUMPING ELEMENT

Corrosion had occurred to a majority of the internal system components as a result of the water/diesel fuel mixture.

Failure of the injection pump delivery valve springs occurred as a result of corrosion.

Failure to the camshaft ball bearing at the governor end of the injection pump was the result of severe service to the pump and contamination of lubricating oil.

Pitting on the load surfaces of the cam lobes was also attributed to contamination of the lubricating oil.

Contamination of lubricating oil and wear to internal components of the injection pump may be reduced significantly by pressure lubrication of the pump's plungers and barrels.

Corrosion can be reduced by the addition of corrosion inhibitors to the emulsion. Further investigation is required to determine the types of additives which may be used and their effects on combustion and emissions.

Further analysis of lubricating oil samples taken is required to ascertain the constituents and sources of contaminating substances.

L. Bruno, P.Eng.
Head, Combustion Systems Section
Dept. of Engineering & Metallurgy

M.B. Shaw
Senior Technician
Dept. of Engineering & Metallurgy

MS/df
March 31st, 1982

ACKNOWLEDGEMENTS

We would like to express our gratitude to Robert Bosch Corporation, USA and Robert Bosch GmbH, Germany for their technical assistance during the component analysis stage of this program.

The technical assistance and valued comments from Mr. Don Dainty of Energy, Mines and Resources Canada, and Dr. R.S. Agarwal of the Department of Supply and Services is also gratefully acknowledged.

Financial support for this program was provided by Energy, Mines and Resources Canada.

REFERENCES

1. "Alternate Fuels", International Congress and Exposition, Society of Automotive Engineers, Publication SP-480, Warrendale, PA, 1981.

2. Wood, C.D., "Alternative Fuels in Diesel Engines - A Review", Society of Automotive Engineers, Publication 910248, Warrendale, PA, 1981.

3. Coon, C.W., Jr., "Multi-Cylinder Diesel Engine Tests with Unstabilized Water-in-Fuel Emulsions", Society of Automotive Engineers, Publication 810250, Warrendale, PA, 1981.

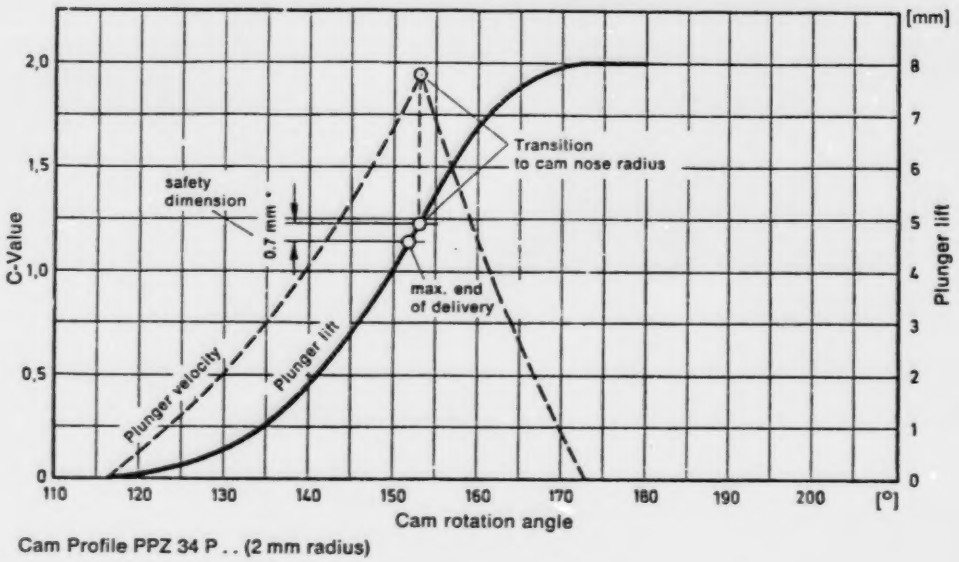
4. Lawson, A., Last A.J., "Modified Fuels of Diesel Engines by Application of Unstabilized Emulsions", Society of Automotive Engineers, Publication 790925, Warrendale, PA, 1979.

5. Last, A.J., "The HydroShear - Diesel Fuel/Water Emulsions", 2nd Symposium on Emulsified Fuels in Combustion, Cambridge, Ma., 1978.

APPENDIX I

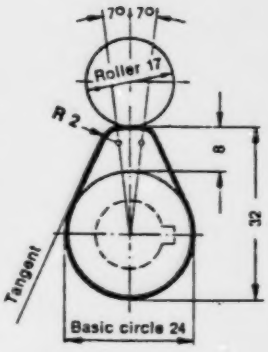
BOSCH INJECTION PUMP
SIZE "A" SPECIFICATIONS

SPECIFICATIONS FOR BOSCH INJECTION PUMP - SIZE "A"



Cam Profile PPZ 34 P . . (2 mm radius)

Cam Profiles



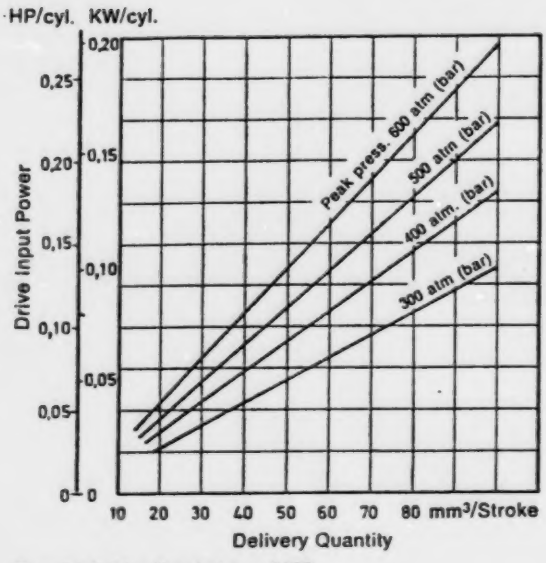
Cam profile PPZ 34 P 26
for 2-, 5-, 6- and multi-cylinder engines

Design	Aluminum alloy housing
Construction	In-line pump, open construction
Number of Cylinders	2- to 12-cylinder versions
Type of Operation	Diesel fuel, AM for dual- or multi-fuel
Mounting	Cradle or flange mounting
Installation Position	See Pg. 19, AKP 1/1 B
Drive System	Coupling or gear
Injection Sequence	As required by engine
Pump Rotation	CW or CCW
Plunger Lift	8 mm
Plunger Diameter	5; 5.5; 6; 6.5; 7; 7.5; 8; 8.5; 9 mm
Rack Travel	21 mm
Cam Profile	See cam profiles.
Max Speed	1400 RPM
Peak Pressure	See Pg. 10, AKP 1/1 B
Drive Input Requirement	See graphs.
Peak Drive Torque	See graphs.

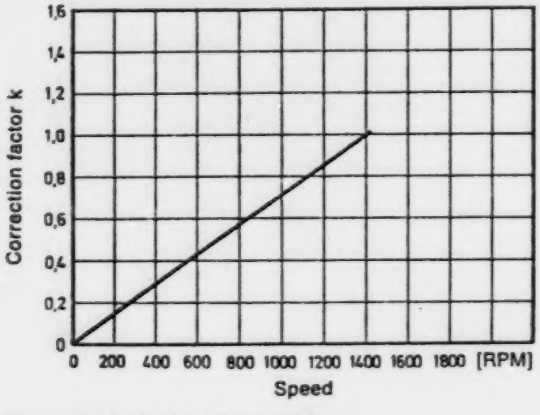
Force required to move control rack, in kgf (with 9 mm plunger)	Speed RPM	Number of cylinders 2 to 6	8	10	12
	0	0.15	0.2	0.23	0.25
	1000	0.05	0.1	0.13	0.15

Delivery quantity, injection duration	See graphs.							
Prestroke[1]) and Retraction Volume	Plunger dia. mm	Standard prestroke mm	Retraction Volume mm³					
	5; 5.5; 6 6.5; 7; 7.5 8; 8.5; 9	1.7 to 1.8 1.9 to 2.0 2.15 to 2.25	35; 50 or 70 35; 50 or 70 35; 50 or 70					
Tube Fittings	Nominal Width	Thread Size	Tubing Diameter Steel	Flexible				
Injection lines: Supply lines: Return:	— 8 8	M 12x1.5 M 14x1.5 M 14x1.5	6x2; 6x2.25 10 x 1 10 x 1	— 8 ID 8 ID				
Lube Oil								
Supply lines Return	4 8	M 10x1 M 14x1.5	6 x 1 10 x 1	4 ID 8 ID				
Oil Block only on **AM**								
Supply line	3	—	4 x 0.5	3 ID				
Lubrication	Connected to engine lubrication system							
Weight in kg	Number of cylinders							
	2	3	4	5	6	8	10	12
PE . . A . .	3.3	4.4	5.3	6.3	7.2	9.2	11.4	13.5
PES . . A . .	3.6	4.6	5.5	—	7.5	9.5	—	—
PE . . AM . .	3.6	4.7	5.6	—	7.5	9.5	—	13.8
PES . . AM . .	3.9	5.0	5.9	—	7.8	9.8	—	—

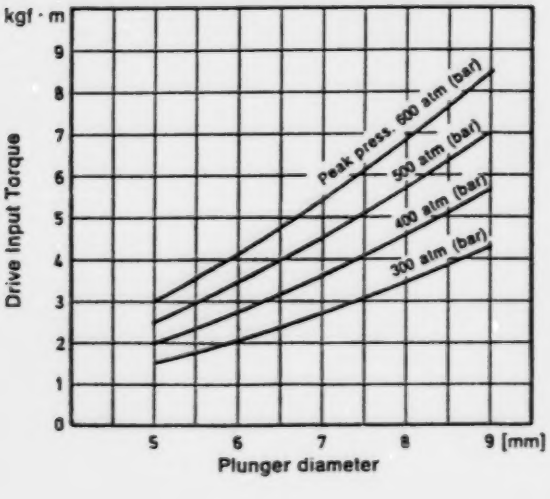
SPECIFICATIONS FOR BOSCH INJECTION PUMP - SIZE "A"



Required drive input at n = 1400

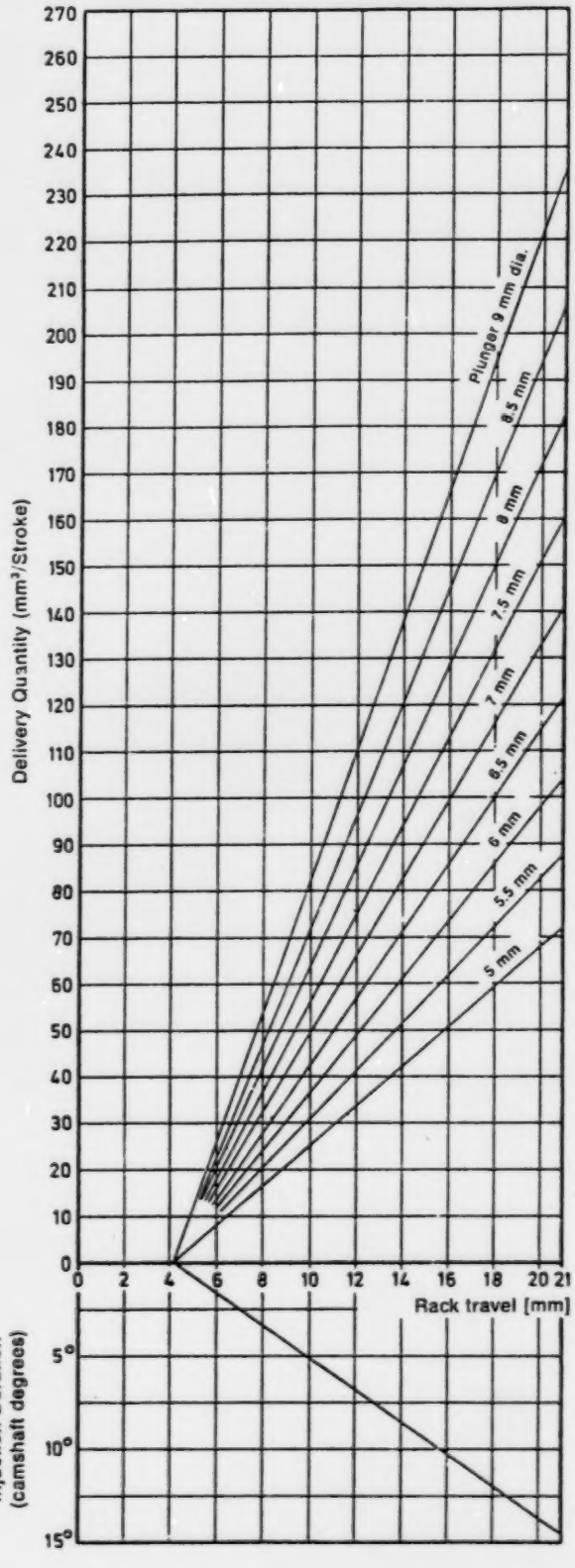


Correction factor for other speeds



Peak drive torque

Performance Curves



maximum Delivery Quantity and Injection Duration

APPENDIX II

ANALYSIS AND CONCLUSIONS
BY
ROBERT BOSCH CORPORATION, GERMANY

ROBERT BOSCH CORPORATION ROBERT BOSCH

Subsidiary of Robert Bosch GmbH

Mr. Mike Shaw
Ontario Research Fondation
Sheridan Park Research Community
Mississauga, Ontario
Canada L5K 1B3

cc: O/EDI1-DN

BROADVIEW, ILLINOIS

2/12/82

Dear Sir,

Subj.: Evaluation of sample fuel injection pump sent by you after endurance tests at ORF- your letter dated Sept. 8,81.

The sample pump has been evaluated by our development department in Germany and following are their findings:

PUMP:

- Delivery valve springs:
  All the springs have rust spots and are broken after the 1st or 2nd coil. Spring breakage is mainly due to rust and in some cases also due to wear caused by rubbing of spring I.D. with the delivery valve pin and filling piece in delivery valve holder.

- Governor end ball bearing:
  All components of this bearing show severe fatigue, especially the inner race. The brass cage is cracked.

All the other parts of the pump are still in working condition. On cams and roller surfaces, especially at the high pressure regions of cam rise, are many indentations due to dirt in lubricating oil.

Rusty areas are also seen at the places mentioned below:

Delivery valve holder:
- High pressure line connecting threads, and the inside diameter where the delivery valve spring rubs against the holder.

Delivery valve: Unground areas of the body and partly on pins.

Element: Large areas on the outside diameter of element barrel collar, partly in suction and leakoil holes and milled regions of helix.

Filling piece: Partly on surface.

and ROBERT BOSCH are trademarks of Robert Bosch GmbH, Stuttgart, Germany

GOVERNOR AND SUPPLY PUMP:

No failure due to wear. Rusty areas were seen on supply pump housing and handprimer plunger which came in contact with test fuel. Light rust seen on supply pump spring. Large amount of dirt was observed in these parts.

CONCLUSIONS:

- From the test conditions it appears that the pump was subjected to quite severe loading. Hence, the failure of the bearing is not considered abnormal.
- The failure of the D.V. springs could be attributed to rust formed due to mixing water in test fuel.
- The pump parts apart from bearing and D.V. springs can be considered to be still in working condition.
- The factors that affect the pump components, while working with a fuel mixed with water, are the idle time of the pump, prevailing temperatures and the composition of water. The parts may rust completely in the event of long idle time. Hence, even though the present test showed good findings, these cannot be generalised for working conditions involving water in fuel.

We are yet to receive the report on the nozzles that were also sent to Germany for evaluation. We will inform you of the findings on these as soon as we receive them.

Sincerely,

ROBERT BOSCH CORPORATION
Manager - O/EDI3- H.Fiedler

O/EDI3/SR/vb

ONTARIO RESEARCH FOUNDATION

ENERGY

energy conservation programs and analysis, thermal insulation design and evaluation, waste heat recovery, building energy systems and monitoring, heat storage systems, thermoelectric generation, combustion technology, burner development, heat transfer analysis, solar systems monitoring, National Solar Test Facility, solar technology, wind power, coal and lignite processing, alternate fuel utilization, battery technology, energy and chemicals from biomass, . . .

ENVIRONMENT

ambient air quality assessment, source sampling, odour emission and control, asbestos measurement and control, pesticide residues, trace metal analysis, trace organic analysis, mutagenic testing, occupational health surveys and assessments, water surveys, water purification, municipal and industrial waste water treatment processes, membrane separation techniques, wet oxidation, diesel emission control technology, solid waste treatment and recovery, noise and vibration analysis, environmental impact assessments, long-range transport of atmospheric pollutants, radiation measurements, particulate identification and measurement, ergonomics and industrial design, air pollution control technology, hazardous and toxic materials and waste control, . . .

MATERIALS

building materials, plastics, coatings and composites, metals, glass and ceramics, wood and wood composites, biomaterials, adhesives and printing inks, yarns, fabrics and geotextiles, leather, organic and inorganic chemicals, specialty formulations, specification development, quality control, mechanical chemical and thermal properties, test method development, failure analysis, fire and flammability, glass-metal seals, metal and alloy powders, metallography, materials characterization by electron microscopy and X-ray microanalysis, photovoltaics and ionic conductors, corrosion properties and control, rubber technology, energy radiography, non-destructive testing, X-ray analysis, cement and concrete, gypsum, . . .

PRODUCTS & PROCESSES

pulp and paper products, clothing, footwear and industrial textile products, knitting technology, thin and thick film systems, electronic devices, microcomputer systems and applications, fibre optics, electronic design, bioengineering, ultrasonic and fluid shear devices, microwave drying, transportation and equipment testing, mathematical stress and vibration analysis, product, equipment and machinery design and development, fuel emulsification, chemistry of foodstuffs, pulping and papermaking processes, ceramics processing, metallurgical process development, powder metal technology, packaging applications, technical and economic evaluations, industrial engineering applications, electroplating, radioactive decontamination, process control, biotechnology, industrial microbiology, enzyme analysis, cryogenics, electrical testing, . . .

RESOURCES

mineral processing, hydro and pyrometallurgical processing of ferrous and non-ferrous ores, coal evaluation and processing, asbestos processing and applications, uranium processing, forest utilization, utilization of forest and agricultural wastes, utilization of industrial mining and domestic wastes, energy and chemicals from biomass, non-metallic minerals, . . .

ONTARIO RESEARCH FOUNDATION • SHERIDAN PARK, MISSISSAUGA, ONTARIO, CANADA L5K 1B3 • (416) 822-4111 • TELEX 06-982311